

इंटरनेट

मानक

Disclosure to Promote the Right To Information

Whereas the Parliament of India has set out to provide a practical regime of right to information for citizens to secure access to information under the control of public authorities, in order to promote transparency and accountability in the working of every public authority, and whereas the attached publication of the Bureau of Indian Standards is of particular interest to the public, particularly disadvantaged communities and those engaged in the pursuit of education and knowledge, the attached public safety standard is made available to promote the timely dissemination of this information in an accurate manner to the public.

“जानने का अधिकार, जीने का अधिकार”

Mazdoor Kisan Shakti Sangathan

“The Right to Information, The Right to Live”

“पुराने को छोड़ नये के तरफ”

Jawaharlal Nehru

“Step Out From the Old to the New”

IS 5878-4 (1971): Code of practice for construction of tunnels conveying water, Part 4: Tunnel supports [WRD 14: Water Conductor Systems]



“ज्ञान से एक नये भारत का निर्माण”

Satyanarayan Gangaram Pitroda

“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

BLANK PAGE



IS : 5878 (Part IV) - 1971

(Reaffirmed 1990)

Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION
OF TUNNELS CONVEYING WATER

PART IV TUNNEL SUPPORTS

Fifth Reprint MARCH 1996
(Incorporating Amendment No. 1)

UDC 624.191.1:624.023.9

© *Copyright* 1979

BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI 110002

Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART IV TUNNEL SUPPORTS

Water Conductor Systems Sectional Committee, BDC 58

Chairman

SHRI P. M. MANE

Ramalayam, Pedder Road, Bombay 26

Members

SHRI K. BASANNA
SHRI N. M. CHAKRAVORTY
CHIEF CONSTRUCTION ENGINEER
SUPERINTENDING ENGINEER
(TECHNICAL/CIVIL) (*Alternate*)
CHIEF ENGINEER (CIVIL)
SUPERINTENDING ENGINEER
(CIVIL AND INVESTIGATION
CIRCLE) (*Alternate*)
CHIEF ENGINEER (CIVIL)
CHIEF ENGINEER (IRRIGATION)

SHRI J. WALTER (*Alternate*)
DEPUTY DIRECTOR (DAMS I)
DIRECTOR

SHRI H. L. SHARMA (*Alternate*)
SHRI D. N. DUTTA
SHRI O. P. DUTTA
SHRI J. S. SINGHOTA (*Alternate*)
SHRI R. G. GANDHI
SHRI M. S. DEWAN (*Alternate*)
SHRI K. C. GHOSAL
SHRI A. K. BISWAS (*Alternate*)
SHRI M. S. JAIN
SHRI B. S. KAPRE

SHRI R. S. KALE (*Alternate*)
SHRI Y. G. PATEL
SHRI C. K. CHOKSHI (*Alternate*)
SHRI A. R. RAICHUR
SHRI S. RAMCHANDRAN

SHRI K. N. TANEJA (*Alternate*)

Representing

Public Works Department, Government of Mysore
Damodar Valley Corporation, Dhanbad
Tamil Nadu Electricity Board, Madras

Andhra Pradesh State Electricity Board, Hyderabad

Kerala State Electricity Board, Trivandrum
Public Works Department, Government of Tamil
Nadu

Central Water & Power Commission, New Delhi
Land Reclamation, Irrigation & Power Research
Institute, Amritsar

Assam State Electricity Board, Shillong
Beas Designs Organization, Nangal Township

The Hindustan Construction Co Ltd, Bombay

Alokudyog Cement Service, New Delhi

Geological Survey of India, Calcutta
Irrigation & Power Department, Government of
Maharashtra

Patel Engineering Co Ltd, Bombay

R. J. Shah & Co Ltd, Bombay
National Projects Construction Corporation Ltd,
New Delhi

(*Continued on page 2*)

IS : 5878 (Part IV) - 1971

(Continued from page 1)

Members

SECRETARY

SHRI G. N. TANDON

SHRI D. AJITHA SIMHA,
Director (Civ Engg)

Representing

Central Board of Irrigation & Power, New Delhi
Irrigation Department, Government of Uttar
Pradesh

Director General, ISI (*Ex-officio Member*)

Secretary

SHRI BIMLESH KUMAR

Assistant Director (Civ Engg), ISI

Panel for Construction of Tunnels, BDC 58 : P2

Convener

SHRI B. S. KAPRE

Irrigation & Power Department, Government of
Maharashtra

Members

SHRI R. S. KALE (*Alternate to*
Shri B. S. Kapre)

SHRI C. K. CHOKSHI
DEPUTY DIRECTOR (DAMS I)

SHRI M. S. DIWAN

SHRI K. C. GHOSAL

SHRI A. K. BISWAS (*Alternate*)

SHRI A. R. RAICHUR

SHRI G. L. RAMASWAMIAH

SHRI S. A. VIJAYAKEERTI (*Alternate*)

SHRI K. SHAMA RAO

SHRI A. S. NARAYANAN (*Alternate*)

SHRI G. N. TANDON

Patel Engineering Co Ltd, Bombay
Central Water & Power Commission, New Delhi
The Hindustan Construction Co Ltd, Bombay
Alokudyog Cement Service, New Delhi

R. J. Shah & Co Ltd, Bombay
Indian Hume Pipe Co Ltd, Bombay

Kerala State Electricity Board, Trivandrum

Irrigation Department, Government of Uttar
Pradesh

Indian Standard

CODE OF PRACTICE FOR CONSTRUCTION OF TUNNELS CONVEYING WATER

PART IV TUNNEL SUPPORTS

0. FOREWORD

0.1 This Indian Standard (Part IV) was adopted by the Indian Standards Institution on 27 October 1971, after the draft finalized by the Water Conductor Systems Sectional Committee had been approved by the Civil Engineering Division Council.

0.2 Very few tunnels are located in perfectly intact strata throughout their whole lengths, the vast magnitude being driven through rock with defects of one kind or another and requiring some support until the permanent lining can be placed. Even intact rock in areas of high initial stresses may require support to prevent popping. Moreover, construction of tunnels involves a large number of problems because of the great longitudinal extent of the work and many kinds of conditions are encountered which for maximum economy should be treated differently. In view of this it has been appreciated that it would be futile to prepare a rigid set of rules or procedures which shall be enforced without leaving any latitude for the exercise of discretion by the site engineer. The aim of this standard is to summarize the well known and proved principles and to describe the commonly used procedures and techniques for providing guidelines which would permit the site engineer to use his discretion.

0.3 In view of the inherent advantages of steel supports over timber supports, the use of the former is recommended and only steel supports are covered in this standard. In olden days timber was used in tunnel supports but now steel has become almost universally adopted as the standard material for supporting tunnels. Sometimes, however, timber may have to be used for tunnel supports.

0.3.1 Steel supports have the following advantages over timber supports:

- a) Steel ribs are easier to handle and require much less storage space;
- b) Steel ribs when compared to timber would be smaller, section-wise and as such overall cross-sectional area of excavation will be less;

- c) Steel ribs become a part of permanent lining and also act as reinforcement. Thus, the thickness of lining will be less;
- d) Steel ribs do not deteriorate like timber;
- e) Steel ribs can be fabricated to the required shape beforehand in the shop and, therefore, their erection is faster; and
- f) No specially skilled personnel are required for erection of steel supports.

0.4 This standard is being published in parts. Other parts of this standard are as follows:

- Part I Precision survey and setting out
- Part II Underground excavation in rock
- Part III Underground excavation in soft strata
- Part V Concrete lining
- Part VI Steel lining
- Part VII Grouting

0.5 This standard is one of a series of Indian Standards on tunnels. Other related standards so far published are given on the fourth cover page.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

0.7 This standard does not cover design of tunnel supports for which a reference should be made to IS : 4880 (Part VI)-1971†.

1. SCOPE

1.1 This standard (Part IV) deals with the types, selection, fabrication and method of fixing of steel supports, rock bolts and shotcreting for tunnels.

2. TERMINOLOGY

2.0 For the purpose of this standard the following definitions shall apply.

2.1 Blocking — It is provided between rock and the ribs to transfer the rock load to the ribs.

*Rules for rounding off numerical values (revised).

†Code of practice for design of tunnels conveying water: Part VI Tunnel supports.

2.2 Bracing — It is provided between ribs/posts to prevent their buckling or shifting, unless this purpose is served by lags attached to the frame.

2.3 Bridge Action Period — It is the time which elapses between firing the shots and the breakdown of the equilibrium of the half dome of unsupported section beyond the last rib of the tunnel supports.

2.4 Crown Bars — These are located at the crown of the tunnel parallel to the centre line.

2.5 Lag — The elements which compose lagging (*see* 2.6).

2.6 Lagging — These are those members of a tunnel support which span the space between the main supporting ribs.

2.7 Minimum Excavation Line (A-Line) — It is the line within which no unexcavated material of any kind and no supports other than permanent structural steel supports shall be permitted to remain.

2.8 Packing — It is the material which is used to fill the empty space between the lagging and rock surface.

2.9 Payline (B-Line) — It is an assumed line (beyond A-Line) denoting mean line to which payment of excavation and concrete lining is made whether the actual excavation falls inside or outside it.

2.10 Rib; Rib and Post or Rib, Post and Invert Strut — These are the components of support system.

2.11 Rock-Load — It indicates the height of the mass of rock which tends to exert pressure on the support.

2.12 Shotcrete — Concrete sprayed under pressure.

2.13 Truss Panels — These serve a function similar to that of crown bars. These are located at the spring line and constitute a temporary support for ribs while taking out the bench and are replaced by posts in the final stage of erection.

2.14 Tunnel Support — It is the structure erected in the tunnel to support the strata surrounding the excavated space until the permanent lining is placed.

2.14.1 Permanent Supports — These are tunnel supports which are left in place permanently.

2.14.2 Temporary Supports — These are tunnel supports which are erected during excavation and removed before erection of either the permanent lining or permanent supports.

2.15 Wall Plates — These serve as sills for ribs and transmit the load from ribs through blocks or posts to the rock.

3. MATERIAL

3.1 Structural steel sections for tunnel supports shall conform to IS : 808-1964* and IS : 226-1969†.

3.2 Concrete shall generally conform to IS : 456-1964‡.

4. GEOLOGICAL SURVEY

4.1 Necessary geological surveys shall be conducted and a geological section through the centre line of the tunnel shall be prepared showing the approximate position of the boundaries of different types of strata and all the faults or fault zones discovered during the survey. During the survey, defects should receive special consideration. On the basis of the geological survey a geological report shall be prepared containing detailed descriptions of the observed defects in geological terms as well as a tentative classification of the defective rocks in the terms, such as intact, stratified, moderately jointed, blocky and seamy, crushed, squeezing and swelling.

5. TYPES OF STEEL SUPPORT SYSTEMS

5.1 Rock tunnel support systems of steel may be generally classified into the following principal types:

- a) Continuous ribs (see Fig. 1A);
- b) Rib and post (see Fig. 1B);
- c) Rib and wall plate (see Fig. 1C);
- d) Rib, wall plate and post (see Fig. 1D); and
- e) Full circle rib (see Fig. 1E)

NOTE — Invert strut may be used in addition, with types (a) to (d) where mild side pressures are encountered (see Fig. 1F).

6. SELECTION OF TYPE OF SYSTEM

6.1 General — When choosing the type of support system, the following factors shall be considered:

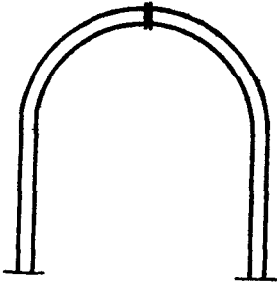
- a) Method of attack;
- b) Rock, characteristics, its behaviour and development of rock load; and
- c) Size and shape of the tunnel cross section.

6.2 Selection of Supports with Reference to Surrounding Strata and Shape of Tunnel

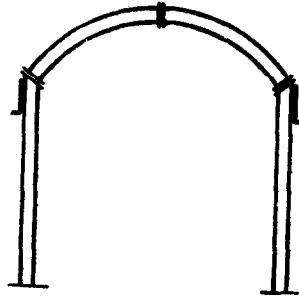
*Specification for rolled steel beam, channel and angle sections (revised).

†Specification for structural steel (standard quality) (fourth revision).

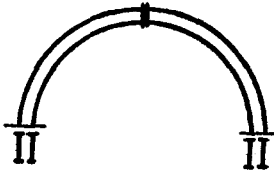
‡Code of practice for plain and reinforced concrete (second revision).



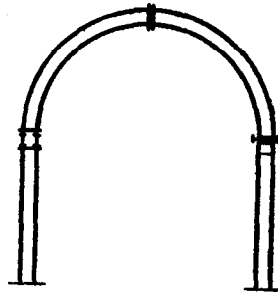
1A CONTINUOUS RIBS



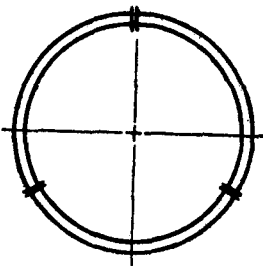
1B RIB AND POST



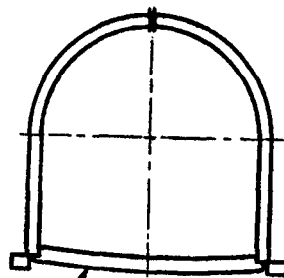
1C RIB AND WALL PLATE



1D RIB WALL PLATE AND POST



1E FULL CIRCLE RIB



1F CONTINUOUS RIB WITH
INVERT STRUT

NOTE — Joints have not been shown in Fig. 1A to 1F and may be located depending upon the construction and fabrication convenience.

FIG. 1 TYPES OF STEEL SUPPORT SYSTEMS

6.2.1 Continuous Ribs — This type can be erected more rapidly than the other types and is generally recommended for use in rocks whose bridge action period is long enough to permit removal of gases and mucking. Invert strut may be used in addition where mild side pressures are encountered (*see* Fig. 1F).

6.2.2 Rib and Post — This type is generally recommended for use in tunnels whose roof joins the side walls at an angle instead of a smooth curve. It may also be used in large tunnels, such as double-track rail road or two-lane highway tunnels, to keep the size of the rib segments within handling and transporting limitations. Invert strut may be used in addition where mild side pressures are encountered (*see* Fig. 1F).

6.2.3 Rib and Wall Plate — This type is generally recommended for use in tunnels with a large cross section with high straight sides through good rock or in large circular tunnels, where it is possible to support the wall plate by pins and where the strata below the wall plate does not require support. This type of support may also be used for tunnelling through spalling rock, provided spalling occurs only in the roof. However, in many cases it is extremely difficult to establish adequate support for the wall plate at any point above the floor-line due to irregularity of the overbreak.

6.2.4 Rib, Wall Plate and Post — This type of support permits post spacing to be different from the rib spacing and is generally recommended for use in tunnels with high vertical sides. Invert strut may be used in addition, where mild side pressures are encountered (*see* Fig. 1F).

6.2.5 Full Circle Rib — This type is recommended for use in tunnels in squeezing, swelling and crushed rock, or any rock that imposes considerable side pressure.

6.3 Selection of Supports with Reference to Method of Attack for Tunnel

6.3.1 All the types of supports mentioned in 5.1 are suitable for the full face method of attack for rock where required bridge action period for providing supports is available.

6.3.2 Rib and wall plate or rib, wall plate and post are suitable for heading and bench method. The rib, wall plate and post type may be supplemented by truss panels or crown bars, which are accessories developed to handle heavy loads that come quickly by supporting the intervening ribs while the bench is shot out.

6.3.3 Where it becomes necessary to drive first the top heading only due to bad roof conditions the rib and wall plate type of support is generally recommended for use in the heading, and post may or may not be used when the bench is taken out depending on rock conditions.

6.3.4 Where for driving a large size tunnel in poor rock conditions, the side drift method is used, the rib, wall plate and post type of supports are recommended; the wall plate, however, being flat. The posts and wall plates are erected in the drift which is driven ahead at each side at subgrade (see Fig. 2)

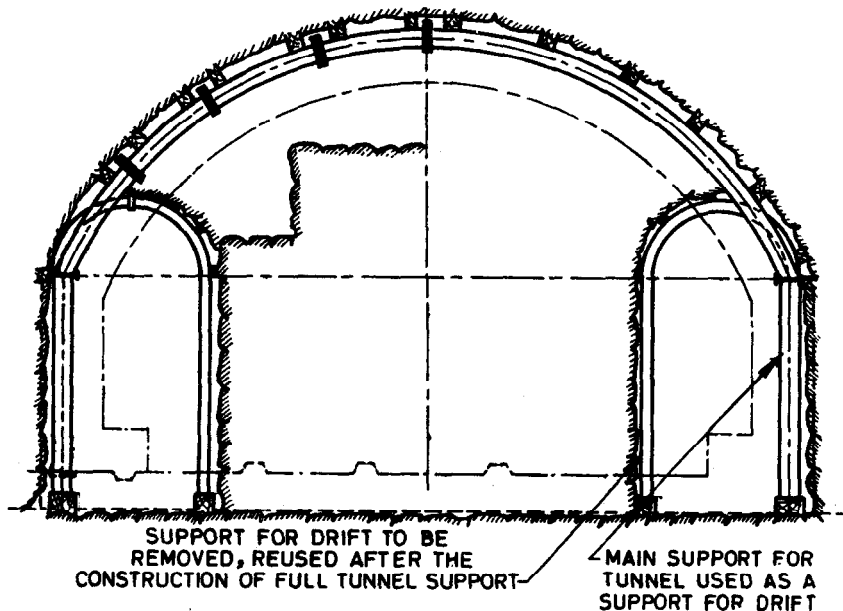


FIG. 2 SIDE DRIFT METHOD

6.3.4.1 Where extreme conditions are encountered, however, break-ups to the crown may be made, leaving a central core. Temporary posts may be quickly placed between the core and the roof at dangerous spots, and crown bars may be slid forward to quickly catch up the roof. The roof ribs should then be placed on the wall plates and securely blocked to take the roof load, after which the temporary posts may be removed.

6.3.4.2 The side drifts themselves usually need support which should be removed just prior to shooting out the core of the main tunnel and re-used ahead. The support system used for the drifts is hybrid. The outer side consists of the posts and wall plate which later becomes a part of the support for the main tunnel, whereas the inner side is a continuous rib (see Fig. 2).

6.4 Type of Support for Shafts — For shafts, usually, the full circle rib or segmental ribs are recommended depending upon the slope and rock conditions. In vertical shafts, ribs may be hung from top by hanger rods and blocked and packed. The spacing of hanger rods may be worked out as in the case of tie rods keeping in view that they shall be strong enough to support the weight of ribs.

7. COMPONENTS OF TUNNEL SUPPORTS

7.1 Design of various components of tunnel supports shall be done in accordance with IS : 4880 (Part VI)-1971*.

7.2 Ribs — Ribs may be made of structural beams. H-beams or wide flange beams should be preferred to I-beams, as the wider flanges provide more surface for blocking and lagging, and the section has greater resistance against twisting. Channel sections are not recommended as their unsymmetrical section is prone to twisting, and their flanges are narrow. In small tunnels, however, channels bent about their minor axis may be used under ordinary loads. When choosing the profiles with different weights, it is advisable to select beams of equal depth.

7.3 Posts — The spacing between the posts may be normally equal to that of the ribs. However, by inserting wall plate between the ribs and the posts the spacing of the posts can be made independent of ribs. The posts should be made of H-sections. The depth of these should normally be the same as that of the ribs though in many cases they may be of lighter sections as long as no side pressure is present.

7.4 Invert Struts — Where side pressures are present and tunnel section has not been converted to a full circle, it is necessary to prevent the inward movement of the rib or post feet and in such cases, invert struts should be provided at tunnel subgrade. They should be so attached to the vertical members that they receive the horizontal pressure. They may be curved to form an inverted arch where there is upthrust from the floor.

7.5 Wall Plates — The following three types of wall plates are commonly used:

- a) Double beam,
- b) Single beam, and
- c) Flat wall plate.

7.5.1 The double and single beam wall plates which are intended to resist bending in vertical planes are recommended for use to transmit the

*Code of practice for design of tunnels conveying water: Part VI Tunnel supports,

loads from the ribs on to blocks or posts with a spacing different from that of the ribs. Flat wall plates merely serve as an erection expedient and a convenient surface for horizontal blocking, their resistance to bending in vertical planes being very small; whenever flat wall plates are used, a post shall be placed under each rib.

7.5.2 Double beam wall plates may be made of two I-beams placed side by side, webs vertical, with about a 100 mm space between flanges to give access to the clamping bolt and admit concrete (see Fig. 3). The beams should be spaced by vertical diaphragms welded under each rib seat. Ribs and posts should be clamped by toggle plates and bolts, thus avoiding the time required for matching bolt holes. This method of attachment also permits variable spacing of either or both the ribs and the posts. This type of beam provides a broad surface of contact for blocking and to engage ribs and posts. Its box section makes it stable with respect to rolling and twisting.

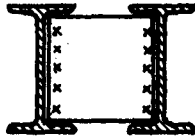


FIG. 3 DOUBLE BEAM WALL PLATE

7.5.3 Single beam wall plates may be H-beams, with web vertical. To enable them to transmit vertical loads from rib to post, they may be reinforced at each rib seat with vertical T-shaped plates, if necessary (see Fig. 4). Attachment of ribs and posts shall be made by bolting through the flanges.



FIG. 4 SINGLE BEAM WALL PLATE

7.5.4 Flat wall plates may be I-beams or wide flange beams used with their webs horizontal. They function merely as a cap for the posts and a sill for erecting roof ribs. The web shall be punched with vent holes to prevent trapping of air when concrete is poured. These holes also serve to pass reinforcing rods if the concrete is reinforced.

7.6 Crown Bars — Crown bars may be built up of double channels as shown in Fig. 5 or may be H-beams or square timber beams. They are located parallel to the axis of the tunnel either resting on the outer flanges of the ribs already erected (see Fig. 6A) or attached to the ribs in hangers as shown in Fig. 6B. Crown bars are an accessory, a construction expedient intended to carry loads till the rib sets are erected and the loads permanently transferred to them. They have one of the two functions to perform: to support the roof immediately after ventilation and thereby gain time for the installation of ribs and to support the roof or roof ribs over the bench shot thereby relieving or supplementing the wall plates.

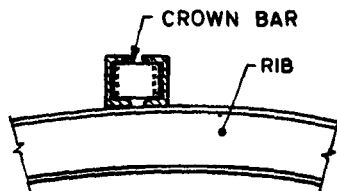


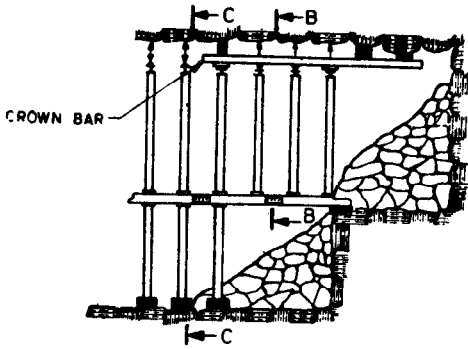
FIG. 5 CROWN BAR

7.7 Truss Panels — These are accessories for use with the combination of rib and post types of support, for the heading and bench or top heading methods of attack and heavy roof loads. Their purpose is to form, in combination with the ribs, a truss to span the gap produced by the bench shot.

7.7.1 The truss panels should be attached to the inside face of the ribs for a distance of one or more ribs ahead of the bench shot as shown in Fig. 7 and should be left there until posts are installed, at which time they should be removed and sent up ahead. Attachment should be by means of only two bolts at each rib. The truss thus formed may even be designed to carry the roof over two bench shots thus making it more convenient to get in the post.

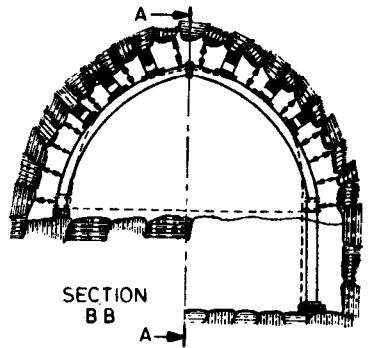
7.7.2 When truss panels are used, no wall plate is required although the flat wall plate may be used to keep the lower ends of the ribs lined up laterally if it is difficult to block the individual ribs against the rock. The truss panels also eliminate the need for wall plate for drifts.

7.8 Bracing — Longitudinal bracing serves to increase the resistance of ribs and posts to buckling about their minor axis and to prevent a displacement of these set members during blasting. If the space between the ribs or posts is bridged by lagging which is firmly attached to the webs, no such bracing is required. The most common types of bracing which is known as tie rods and collar braces are shown in Fig. 8. The braces may, however, be placed as most convenient.



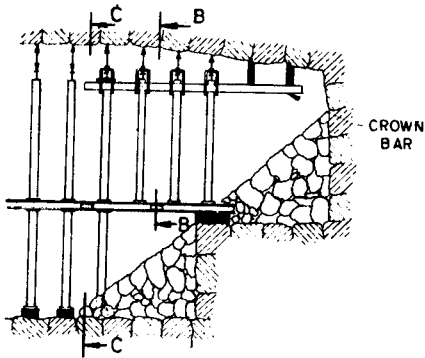
SECTION AA

6A CROWN BARS SUPPORTED OVER RIBS

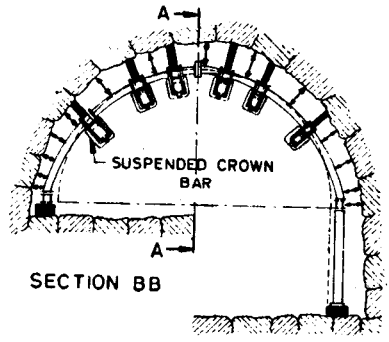


SECTION BB

SECTION CC



SECTION AA



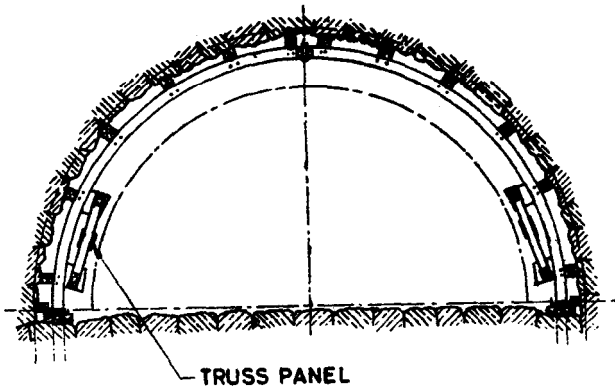
SECTION BB

SECTION CC

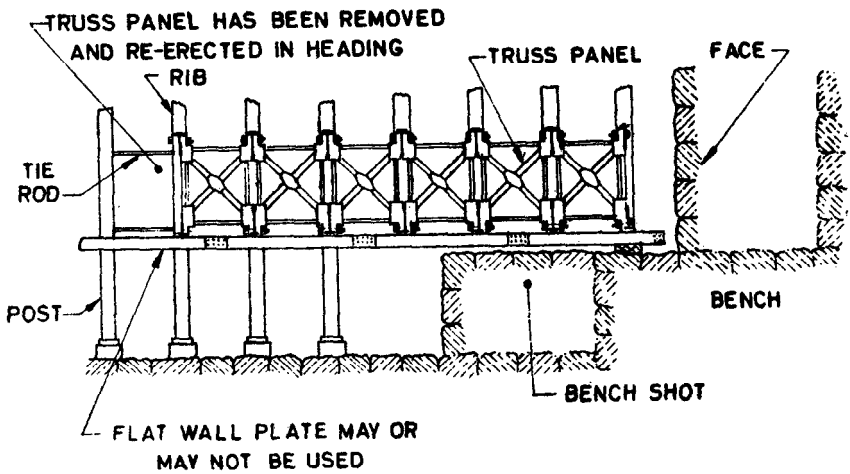
6B CROWN BARS IN HANGERS

- † BLOCKING BETWEEN ROCK AND RIB
- BLOCKING BETWEEN CROWN BAR AND ROCK RIB

FIG. 6 METHOD OF SUPPORT FOR CROWN BARS



CROSS SECTION



LONGITUDINAL SECTION

FIG. 7 TRUSS PANEL

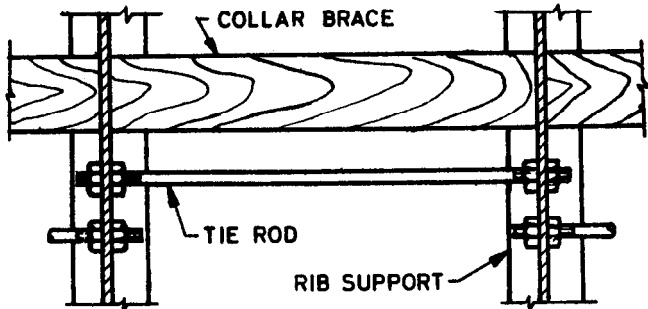


FIG. 8 COLLAR BRACE AND TIE RODS

7.8.1 Tie rods usually may be 15 or 20 mm rods, with thread and two nuts on each end. The length shall be at least 100 mm more than the spacing of the ribs. The spacing of the rods shall be kept such that slenderness ratio l/r for ribs is not greater than 60, where l is the spacing of the rods, and r is the least radius of gyration of the ribs. Collar braces may be usually pieces of timber, 75 × 100 mm, 100 × 150 mm, 150 × 150 mm or of any convenient size. Holes in pairs shall be provided in the web of ribs and posts for the tie rods. Collar braces shall be set in the line between ribs, tie rods inserted and the nuts tightened. Wooden collar braces should be removed before placing final lining.

7.8.2 Spreaders (see Fig. 9) which are additional braces may be angles, channels, or I-beams with a clip angle or plate either bolted or welded on each end to the ribs. These are left in the concrete. In tunnels having steep slopes tie rods may be replaced by spreaders.

7.9 Blocking — It is generally done by using timber pieces tightly wedged between the rock and the rib.

7.10 Lagging — It performs one or more of the following functions:

- To provide protection from falling rock or spalls;
- To receive and transfer loads to the rib sets;
- To provide a convenient surface against which to block in case it is not convenient to block directly against the rib, because of irregular overbreak;
- To provide a surface against which to place back packing;
- To serve as an outside form for concrete lining, if concrete is not to be poured against the rock; and

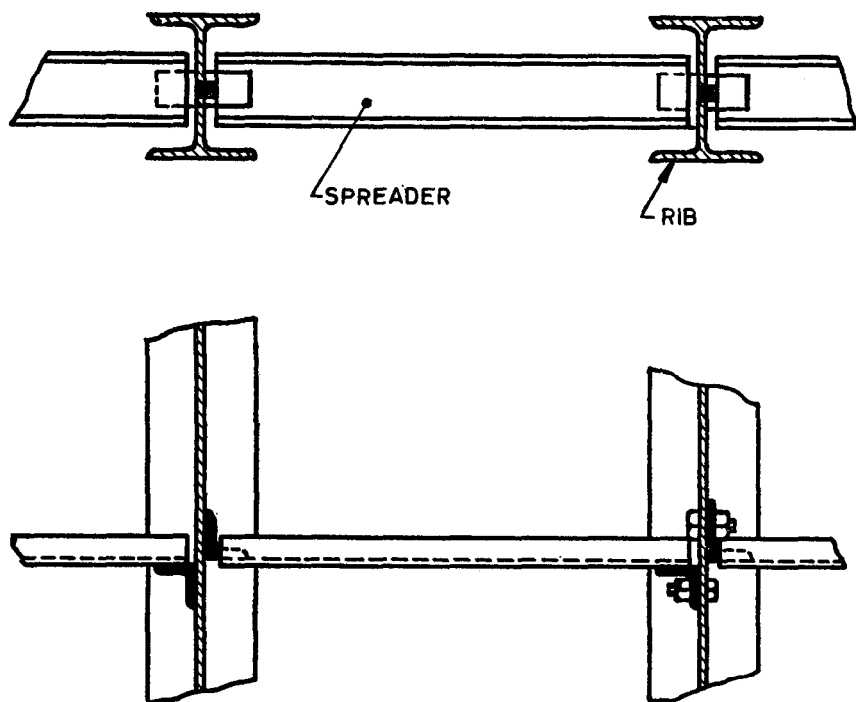


FIG. 9 SPREADER DETAILS

- f) To divert water, and to prevent leaching and honey-combing of concrete.

7.10.1 Lagging may be made either of steel, precast concrete or timber. Steel laggings may be made out of channels, beams, beams and plates and liner plates (see Fig. 10 and 11). Liner plates, which are pressed steel panels may also be used with or without ribs depending upon the rock conditions. It is recommended that use of timber in underground work should be minimized as far as practicable, since timber once fixed can be rarely removed safely and likely to deteriorate and prove a source of weakness. Total prohibition of timber is, however, not practicable.

7.10.2 The spacing of lags shall be closest at the crown, increasing down to spring line. On the side only an occasional lag should be used, if necessary. Close lagging should be employed where rock conditions make it necessary.

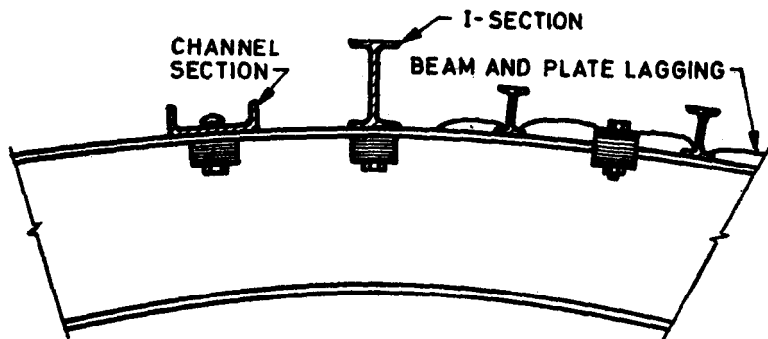


FIG. 10 TYPES OF LAGGING

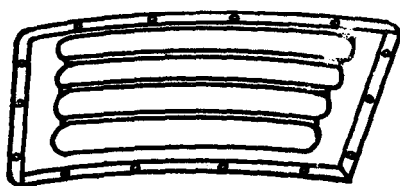


FIG. 11 LINER PLATE

7.11 Packing — The function and type of packing depends on the rock condition. In dry tunnels through jointed rock, packing is only used to fill large cavities produced by excessive overbreak. In broken, crushed or decomposed rock it serves to transfer the rock load to the lags, thereby acting as a substitute for excessive blocking. In squeezing rock it provides continuous contact through the laggings with the rib sets. In jointed water-bearing rock it has primarily the function of a drain.

7.11.1 Dry Packing — Dry pack, which usually consists of tunnel spoil (hard) shoveled or hand packed into the space between the lagging and the rock, is recommended for use only where excessive rock loads are not likely to develop. It should be placed simultaneously with the erection of the lagging. Starting at the lowest point, a few lags should be placed and tunnel spoil (hard) shoveled in behind. This procedure should be carried up to the crown at which point it is necessary to pack endwise.

7.11.2 Concrete Packing — It is recommended for use where considerable rock loads are anticipated. However, its use is not recommended in case the tunnel supports are designed as yielding supports. Concrete packing may be M-100 concrete conforming to IS : 456-1964*. It may be placed by manual labour or by pneumatic placer to the possible extent. Where excessive loads are anticipated, concrete packing should start from the inner flanges of the steel support so as to embed the whole steel supports in concrete. In such cases it is recommended that precast concrete may be used as additional lagging between two adjacent ribs so as to serve the purpose of form work.

7.11.3 Pea Gravel Packing — Pea gravel packing by blowing of gravel is recommended in shield-driven tunnels to fill the annular space around the lining left by the advancing tail of the shield. Gravel should be blown through the grout holes provided in the liner segments as the shield is shifted forward.

NOTE — Pea gravel packing is considered highly desirable kind of packing for most purposes but it has not been practised so far in rock tunnels.

7.11.4 Grouting — Grouting to fill any space outside the concrete lining should be usually done after the main concrete lining is in place. But there are occasions where it is desirable to do grouting at low pressure soon after concrete packing. When the main concrete lining is likely to be delayed considerably it is desirable to do grouting at low pressure after concrete packing.

8. ROOF BOLTS

8.1 General — Roof bolting follows the principle of fastening the loose rocks near the surface to the solid rock above, by means of anchor bolts instead of supporting it from below. Roof bolts not only support the surface rock but also assist it to act as a load carrying element.

8.2 Design — The design of roof bolts shall be done in accordance with IS : 4880 (Part VI)-1971†.

8.3 Types of Roof Bolts — The types of roof bolts used commonly have been described in 8.3.1 to 8.3.3.

8.3.1 Wedge and Slot Bolts — These consist of mild-steel rod, threaded at one end, the other being split into halves for about 125 mm length. A wedge made from 20 mm square steel and about 150 mm long shall be inserted into the slot and then the bolt driven into the hole which will make the split end to expand and fit tight into the hole forming the anchorage. Thereafter, a 10-mm plate washer of size 200 × 200 mm

*Code of practice for plain and reinforced concrete (second revision).

†Code of practice for design of tunnels conveying water: Part VI Tunnel supports.

shall be placed and the nut tightened (see Fig. 12). The efficiency of the splitting of the bolt by the wedge depends on the strata at the end of the hole being strong enough to prevent penetration by the wedge end and on the accuracy of the hole drilled for the bolt. The diameter of such bolt may be 25 mm or 30 mm.

8.3.2 Wedge and Sleeve Bolt—This generally consists of a 20 mm diameter rod at one end of which is a cold-rolled threaded portion. The other end of the rod is shaped to form a solid wedge forged integrally with the bolt and over this wedge a loose split sleeve of 38 mm external diameter is fitted (see Fig. 13). The anchorage is provided in this case by placing the bolt in the hole and pulling it downwards while holding the sleeve by a thrust tube. Split by the wedge head of the bolt, the sleeve expands until it grips the sides of the tube. Special hydraulic equipment is needed to pull the bolts.

8.3.3 Perfo Bolts—This method of bolting consists of inserting into a hole a perforated cylindrical metal tube which has been previously filled with cement mortar and then driving into the tube a plain or ridged bolt. This forces part of the mortar through the perforations in the tube and into intimate contact with the sides of the bore hole thus cementing the bolt, the tube and the rock into one homogeneous whole (see Fig. 14). The relation between the diameter of the bore hole and the diameter of perfo sleeve and bolts is given in Table 1.

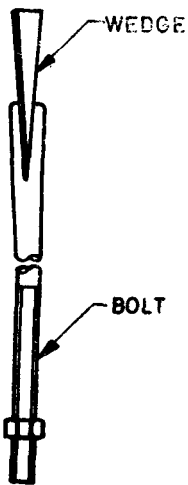


FIG. 12 WEDGE AND
SLOT BOLT

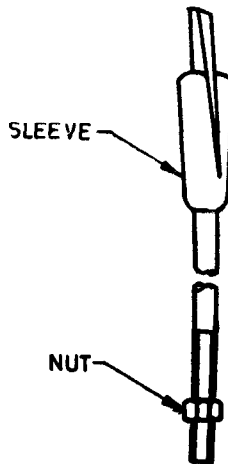


FIG. 13 WEDGE AND
SLEEVE BOLT

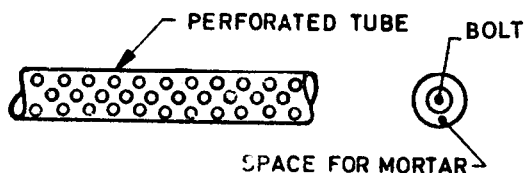


FIG. 14 PERFO BOLT

TABLE 1 DIAMETER OF PERFO SLEEVE AND BOLTS

All dimensions in millimetres.

DIA OF BORE HOLE	DIA OF PERFO SLEEVE	DIA OF BOLTS
(1)	(2)	(3)
40	36	30
38	31	25
31	27	18

9. GUNITING

9.1 It is recommended that guniting with a mix of 1 : 3 to 1 : 4 may be used as a form of temporary support with or without wire mesh to prevent deterioration of rock surface. When used in combination with rock bolts and chain link fabric, it forms a permanent support.

10. SHOTCRETE

10.1 General — Shotcrete for tunnel supports may be used by itself as a thin skin type reinforcement or used in combination with rock bolts, wire mesh and other more conventional tunnel reinforcements. Details are given below:

- Shotcrete is forced into open joints, fissures, seams and irregularities in the rock surface and in this way serves the same binding function as mortar in a stone wall.
- Shotcrete hinders water seepage from joints and seams in the rock and thereby prevents piping of joint filling materials and air and water deterioration of the rock.
- Shotcrete's adhesion to the rock surface and its own shear strength provide a considerable resistance to the fall of loose rock blocks from the roof of a tunnel.
- A thicker shotcrete layer 150 to 250 mm provides structural support, either as a closed ring or as an arch type member.

10.2 Mix — Shotcrete shall be mixture of cement, sand and aggregate. The proportion of cement to aggregate in shotcrete may be normally 1 : 3 or 1 : 4; the aggregate being a mixture of sand and about 20 percent aggregate varying from 5 to 20 mm. The dry mixture of shotcrete shall be applied under pressure of about 3.5 kg/cm² by means of a nozzle through a concrete gun. To this nozzle, water shall be added also under pressure through a separate pipe. A quick setting agent shall be added to the dry mixture.

10.3 Thickness — The thickness of shotcrete required depends upon the type of rock, the extent of stratification and/or joints, blockiness and also the size of the tunnel. The thickness may normally range from 50 to 150 mm and whether it should be used plain or with wire-mesh anchored to rock will depend upon the actual site conditions in each case.

NOTE — As in the case of rock bolts, the application of shotcrete has not yet reached the stage when it is possible to laydown a design criteria. Considerable experience has been accumulated in regard to the use of shotcrete as underground support without any consideration for the type of pressure or rock-shotcrete interaction that was dealt with during construction. The results of such massed experience are frequently expressed in the form of rule-of-thumb guides for the selection of a shotcrete design.

11. FABRICATION

11.1 The ribs shall generally be bent cold. For small jobs ribs may be fabricated as polygons.

11.2 The accuracy of bending shall be such that after bending each segment shall conform to true template at ends. Intermediate portions may depart from true template by not more than ± 10 mm. The web shall be true and wrinkles or buckles shall not exceed 5 mm when measured from a straight edge held flush against either side of web on radial plane.

11.3 To ensure proper space as the crown after wedging, the ribs shall be fabricated to a slightly larger radius than theoretically computed.

11.4 In tunnels with small cross section the crown joints may be 'kicked up' or the ribs set high to accommodate the concrete delivery pipe as shown in Fig. 15.

11.5 All welding for fabrication of supports shall conform to the provisions of IS : 816-1969*.

11.6 Erection Tolerances — The steel supports shall be erected at spacings shown in the drawings and kept blocked and wedged tightly until final concreting. They shall be erected either vertical or in a plane

*Code of practice for use of metal arc welding for general construction in mild steel (first revision).

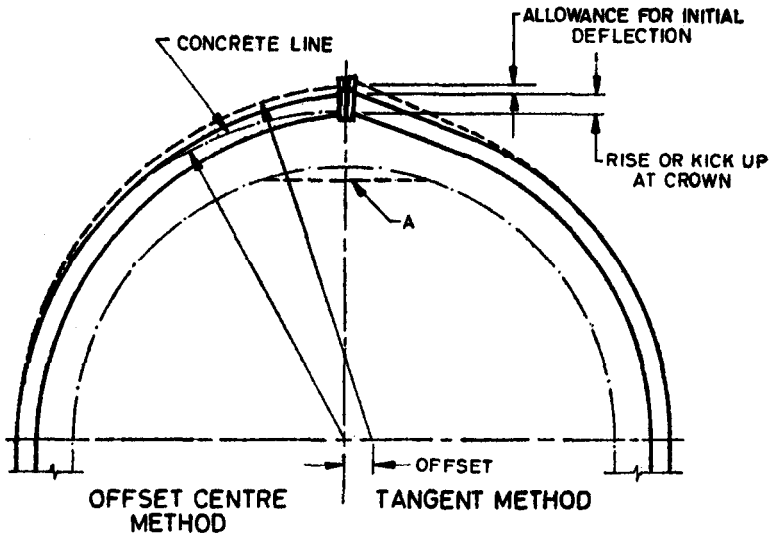


FIG. 15 KICK UP AT CROWN IN RIBS

at right angles to the slope of the tunnel as may be found practicable. The erection shall be done within the following tolerances:

- a) *Spacing of Ribs* — Average of three measurements taken around periphery shall not differ from the spacing shown on the drawings by more than ± 3 cm.
- b) *Internal Dimension* — Dimensions between the inner flanges of ribs shall be checked at 2 or 3 points in the horizontal plane and such dimensions shall not vary from the theoretical dimensions by more than ± 3 cm.
- c) *Level at Crown* — Level of the crown shall be within $- 2$ cm and $+ 4$ cm of the required level.
- d) *Deviation in Vertical Plane* — The deviation from vertical or the required inclination shall not be more than ± 20 mm when measured at the lowest point.
- e) *Spacing Between the Tie Rods* — This shall be as shown on the drawings with a tolerance of ± 3 cm.
- f) *Gap Between the Joints* — The gap between joints of the butt plates of the ribs shall not be more than 5 mm.

BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones: 331 01 31, 331 13 75

Telegrams: Manaksanstha
(Common to all Offices)

Regional Offices:

	Telephone
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002	{ 331 01 31 331 13 75
*Eastern : 1/14 C. I. T. Scheme VII M, V. I. P. Road, Maniktola, CALCUTTA 700054	36 24 99
Northern : SCO 445-446, Sector 35-C, CHANDIGARH 160036	{ 2 18 43 3 16 41 41 24 42
Southern : C. I. T. Campus, MADRAS 600113	{ 41 25 19 41 29 16
†Western : Manakalaya, E9 MIDC, Marol, Andheri (East), BOMBAY 400093	6 32 92 95

Branch Offices:

'Pushpak', Nurmohamed Shaikh Marg, Khanpur, AHMADABAD 380001	{ 2 63 48 2 63 49
‡Peenya Industrial Area 1st Stage, Bangalore Tumkur Road BANGALORE 560058	{ 38 49 55 38 49 56
Gangotri Complex, 5th Floor, Bhadbhada Road, T. T. Nagar, BHOPAL 462003	6 67 16
Plot No. 82/83, Lewis Road, BHUBANESHWAR 751002	5 36 27
53/5, Ward No. 29, R.G. Barua Road, 5th Byelane, GUWAHATI 781003	3 31 77
5-8-56C L. N. Gupta Marg (Nampally Station Road), HYDERABAD 500001	23 10 83
R14 Yudhister Marg, C Scheme, JAIPUR 302005	{ 6 34 71 6 98 32
117/418 B Sarvodaya Nagar, KANPUR 208005	{ 21 68 76 21 82 92
Patliputra Industrial Estate, PATNA 800013	6 23 05
T.C. No. 14/1421, University P.O., Palayam TRIVANDRUM 695035	{ 6 21 04 6 21 17

Inspection Offices (With Sale Point):

Pushpanjali, First Floor, 205-A West High Court Road, Shankar Nagar Square, NAGPUR 440010	2 51 71
Institution of Engineers (India) Building, 1332 Shivaji Nagar, PUNE 411005	5 24 35

*Sales Office in Calcutta is at 5 Chowringhee Approach, P. O. Princep Street, Calcutta 700072

†Sales Office in Bombay is at Novelty Chambers, Grant Road, Bombay 400007

‡Sales Office in Bangalore is at Unity Building, Narasimharaja Square, Bangalore 560002

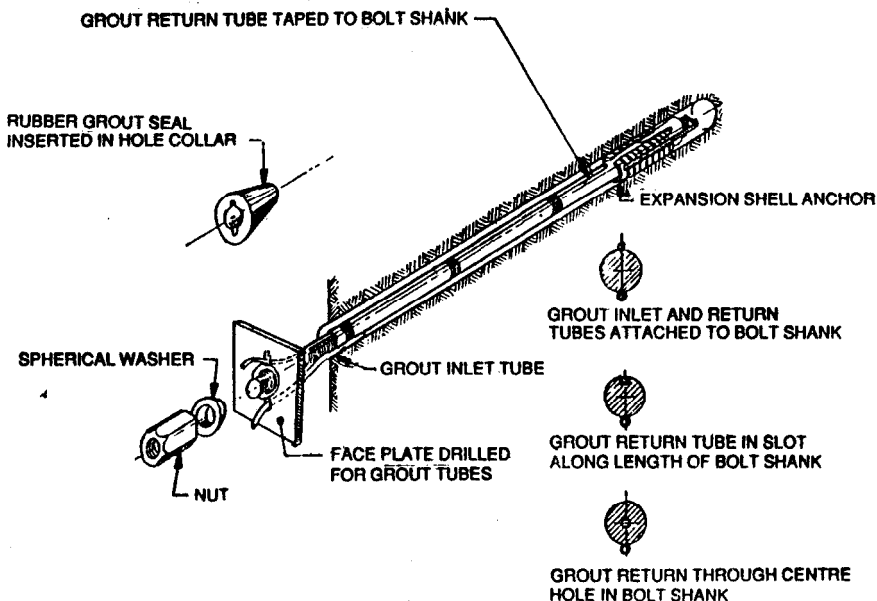
AMENDMENT NO. 2 OCTOBER 1992
TO
IS 5878 (Part 4) : 1971 CODE OF PRACTICE FOR
CONSTRUCTION OF TUNNELS CONVEYING
WATER

PART 4 TUNNEL SUPPORTS

(Page 19, clause 8.3.3) — Insert the following new clauses after 8.3.3:

8.3.4 Mechanically Anchored, Tensioned and Grouted Bolts

This generally consists of a wedge, attached to the bolt shank which is pulled into a conical anchor shell forcing it to expand against the drill hole walls. A rubber grout seal is used to centre the bolt in the hole and to seal the collar of the hole against grout leakage. Grout is then injected into the collar end of the hole and the return pipe is extended for the length of the hole. The grout injection is stopped when the air has been displaced and when grout starts flowing from the return tube (see Fig. 16). These type of bolts can be tensioned immediately after installation and grouted at a later stage when short term movements have ceased.



**FIG. 16 TYPICAL DETAILS OF MECHANICALLY ANCHORED,
TENSIONED AND GROUTED BOLTS**

8.3.5 Resin Grouted, Tensioned Threaded-Bar Bolts

This method of bolting consists of resin and catalyst contained in plastic capsules, the catalyst being separated in a glass or plastic container in the resin. These capsules are pushed into the hole with a loading stick and the bar is then inserted. Rotation of bar during insertion breaks the plastic containers and mixes the resin and catalyst (see Fig. 17). They are very convenient and simple to use. Very high strength anchors can be formed in rock of poor quality. These can be increasingly used in critical applications in which cost is less important than speed and reliability.

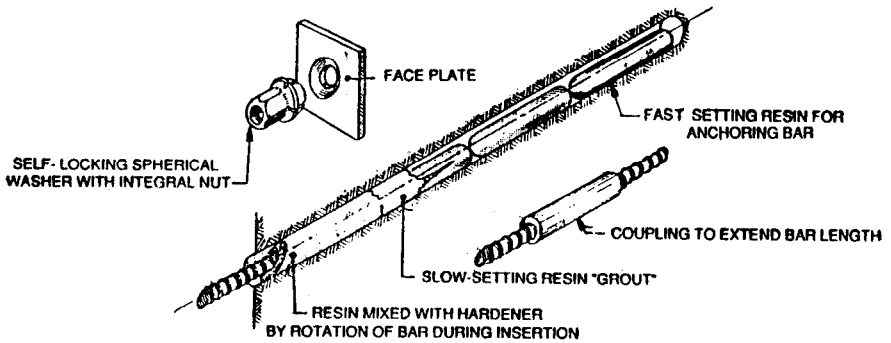


FIG. 17 TYPICAL DETAILS OF RESIN GROUTED, TENSIONED
THREADED BAR BOLTS

(RVD 14)